in either Hamilton or Tait. The truth is it is all there. Hamilton showed long ago that if

$$\phi\rho = \alpha S\lambda\rho + \beta S\mu\rho + \gamma S\nu\rho,$$

then

$$\phi^{-1}\rho = \lambda_1 S\alpha_1\rho + \mu_1 S\beta_1\rho + \nu_1 S\gamma_1\rho,$$

where

$$\alpha_1 S\alpha\beta\gamma = V\beta\gamma, \text{ \&c.}, \ \lambda_1 S\lambda\mu\nu = V\mu\nu, \text{ \&c.}$$

Now Heaviside fusses greatly over this method of inverting ϕ, and any reader of § 172 ("Electromagnetic Theory," in the *Electrician*), would infer that the invention of the name dyadic suggestion this demonstration which Hamilton and Tait had somehow missed in their development of "the very clumsy way" of expressing $\phi^{-1}\rho$ in terms of ρ, $\phi\rho$, and $\phi^2\rho$. But the whole thing is given in Hamilton's "Elements" (p. 438, equation xxvii.), and in Tait's "Quaternions" (p. 89, second edition; p. 123, third edition). I would also refer to § 174 of Tait's third edition (§ 162 of the second), a comparison of which with Heaviside's tall talk in the *Electrician* of November 18, 1892 (§ 171), will show that, on the most lenient hypothesis available, our self-appointed critic of Tait's methods has never really read Tait's "Quaternions." . . .

All through his system Prof. Gibbs has refused to consider the complete product of two vectors. He has used the form $\alpha\beta$ to mean a "dyad" or operator of the form $\alpha S\beta$ or $\beta S\alpha$. What, then, can he mean us to understand by the equations—

$$\iint d\sigma\omega = \iiint dv\nabla\omega \quad ((2) \text{ of } \S\ 164),$$

and

$$\int d\rho\omega = \iint d\sigma \times \nabla\omega \quad ((2) \text{ of } \S\ 165).$$

In quaternion notation the last would be written

$$\int d\rho\omega = \iint V(d\sigma\nabla)\omega.$$

Both equations are quite correct if and only if $d\sigma\omega$, $d\rho\omega$, and $\nabla\omega$ are taken in their quaternion meaning of *quantities*. But Gibbs has wilfully cut himself adrift from this interpretation. How, then, does he interpret these equations?

The chief arguments of the paper may be briefly summarised thus:—

(1) It is maintained that the quaternion is as fundamental a geometrical conception as any that Prof. Gibbs has named.

(2) In every vector analysis so far developed, the versorial character of vectors in product combinations is implied if not explicitly stated.

(3) This being so, it follows as a *natural* consequence that the square of a unit vector is equal to negative unity.

(4) The *assumption* that the square of a unit vector is positive unity leads to an algebra whose characteristic quantities are non-associative, and whose ∇ is not the real efficient *Nabla* of quaternions.

(5) The invention of new names and new notations has added practically nothing of importance to what we have already learned from quaternions.

EXPERIMENTAL MEDICINE.[1]

THIS volume is the fourth number of this remarkable publication, and will prove of surpassing interest to the bacteriologist, physiologist, and physician, chiefly on account of the first paper which it contains.[2]

In 1877 Dr. N. V. Eck invented an operation by which it was possible to alter the circulation in such a manner that the blood flowed from the portal vein into the inferior vena cava without passing through the liver. He succeeded in establishing an artificial opening between these veins in several dogs, and then tied the portal vein near the liver; unfortunately, only one dog lived for any length of time (two and a half months), and, owing to an accident, Dr. Eck was unable to control the result by post-mortem examination. The operation has now been repeated at the St. Petersburg Institute, and it has been found that in successful cases the blood passed entirely from the portal vein into the inferior vena cava.

The animals which successfully resisted this severe operation showed no alteration in the appetite, though after a period of ten days or so their temper underwent marked changes. Although perfectly docile before the operation, they now became bad-tempered, bit everything that came in their way, and showed undue excitement on trifling provocation. The animals became weak, and their gait ataxic, whilst the sensory apparatus was also greatly disturbed, as they often became blind, and appeared to lose all sensation of pain. In a further stage convulsions and coma supervened; though the animals occasionally recovered perfectly after a time, many of them died when the first attack of excitement and convulsions occurred, or succumbed to subsequent attacks, although, on the whole, the latter rarely proved fatal. The temperature showed no changes attributable to the veinous fistula, but the weight generally diminished until death supervened, although, in animals which recovered it reached, or even exceeded, the original weight. The appetite was good, though capricious; but a distinct relation was found to exist between the state of the alimentary canal and the attacks of excitement before mentioned. The animals which absolutely refused to eat meat remained free from the attacks, while the "crises" invariably occurred in the dogs that ate meat voraciously. It is a remarkable fact that many of them learnt by experience that meat was bad for them, and declined to take it.

Some dogs recovered perfectly, and at the postmortem it was found that a collateral circulation had been set up, so that the portal blood again circulated through the liver.

It would appear from further observations that these symptoms are due to the toxic action of the products of the transformation of nitrogenous food, the liver being unable to convert them into urea and uric acid. Carbamic acid was found in the urine of these animals, and carbamate of sodium or calcium, when introduced into a healthy animal's stomach, produced exactly the same symptoms as the fistula above described. On the other hand, it was found impossible to poison healthy dogs with the same salt, provided the setting free of carbamic acid was prevented by the simultaneous introduction of carbonate of soda into the stomach, while the introduction of both salts gave rise to all the symptoms of carbamic acid poisoning, when the circulation through the liver had been interrupted. The authors conclude, therefore, that the carbamates formed during digestion in passing through the liver are transformed into a harmless substance, and that this substance is most probably urea.

In some cases the experimenters removed the entire liver; but the animals never lived more than six hours, and fell at once into a comatose state, followed by convulsions, tetanus, and death through arrest of the respiration. Similar results were obtained by establishing a veinous fistula in the first place and tying the hepatic artery afterwards.

According to Messrs. Hahn and Nencki, who performed the chemical part of these observations, the reaction of the urine remained normal until one of the attacks of excitement set in, when it became alkaline. If the hepatic artery were tied at the same time, the urine contained a little albumin and hæmaglobin, together with small quantities of urobilin and biliary pigment, provided the gall-bladder had not been emptied before the operation. The quantity of urea was always greatly lessened if the hepatic artery were also tied, or the greater part of the liver removed. The relation of the nitrogen in urea to the total quantity of nitrogen excreted was much smaller than normal, being only 77 per cent. instead of 89 per cent. On the other hand, the uric acid in the urine ultimately increased in quantity, even when the hepatic artery was not tied, although the total quantity of nitrogen excreted was not greater than normal, the increase in the uric acid corresponding to the setting in of the convulsions. With regard to the ammonia contained in urine, the authors have come to the following conclusions:—(1) Eck's operation, combined with the ligature of the hepatic artery, causes in dogs an increase in the excretion of ammonia. In some cases this increase is relative only with regard to the nitrogen of urea or the total nitrogen, whereas in other cases it is absolute, and this absolute increase takes place when the animals survive the operation for twenty hours at least; (2) the secretion of ammonia increases rapidly in animals which have been subjected to Eck's operation as soon as the first symptoms set in.

In a further series of researches the authors showed that car-

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[1] "Archives des Sciences biologiques publicés par l'institut impérial de médecine experimentale à St. Pétersbourg," vol. i. no. 4.

[2] "La fistule d'Eck de la veine cave inférieure et de la veine porte, et ses conséquences pour l'organisme, par MM. les Drs. M. Hahn, V. Massen, M. Nencki, et J. Pawlow."

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bamic acid is present in the urine of a normal animal, and increases after Eck's operation. It would be interesting therefore to compare these facts with what we know of the increase of ammonia in pathological states of the liver in man. The liver, however, is not the only place where urea is formed, for the urea never completely disappeared in any of these experiments; and it is well known that in sharks which live seventy hours after the removal of the liver, the urea in the muscles does not diminish after the operation.

Such are the chief new facts we have met with in this interesting memoir, and it is certain that these investigations open up a new field for further researches. The other papers[1] contained in this volume call for little comment; they relate chiefly to the digestive and putrefactive processes taking place in the human intestinal tract.

It will be seen, however, that this fourth number sustains the well-earned reputation of the three first ones, and that the archives deserve to take their place among the chief scientific journals which made their first appearance in the year 1892.

STEAM ENGINE TRIALS.

A PAPER on the last series of steam engine trials undertaken by the late Mr. P. W. Willans was read at the meeting of the Institution of Civil Engineers on April 11.

The paper dealt with an extensive series of condensing trials made with a 40 I.H.P. Willans Central-Valve Engine. These were intended to form a sequel to the investigations described in the author's papers, entitled "Economy Trials of a Non-condensing Steam Engine, Simple, Compound, and Triple," read before the Institution in 1888 and 1889. The principal objects in undertaking these trials were—(1) To ascertain the initial condensation in the first cylinder, and to trace the behaviour of the steam in the succeeding cylinders, when working as a compound or triple-expansion engine; (2) To observe the effect of speed of rotation, area of exposed surface, and range of temperature, upon the initial condensation, and upon economy generally; (3) To ascertain the percentage of the theoretical mean pressure actually obtained; (4) To ascertain the ratio of the work done by each pound of steam to the theoretical work due from it; (5) To determine the consumption of steam at all loads, and under various conditions.

The consumption of steam was determined by discharging the condensed water from the exhaust into a tank carried by a weighbridge, and observing the intervals of time required for fixed weights of water to run in. By this method, a continual watch was kept on the performance of the engine during the whole trial, and any disturbing cause was immediately detected; leaky steam-pipe joints did not affect the result, and the length of the trial might be much reduced. Special experiments, made to ascertain whether any addition was necessary to cover leakage in the engine and exhaust-pipe, showed that this leakage was slight.

The method of determining the theoretical work due from one pound of saturated steam when discharging into a condenser was next considered, and it was shown that the thermal efficiency of a condensing engine must of necessity be less than that of a non-condensing engine, owing to the greater proportionate size of the "toe" of the diagram cut off for practical reasons. In the non-condensing trials the best number of expansions was computed from the approximate formula $p^8 v^7 =$ constant; but for the condensing trials the error in this could not be neglected. The best ratio of expansion and mean pressure were therefore calculated for adiabatic expansion, by Mr. Macfarlane Gray's $\theta\ \phi$ diagram, combined with a volume curve. Altogether sixty-two trials were made under various conditions of speed, steam-pressure, load, and ratio of expansion, as well as with the engine working simple, compound, and triple, and the results were embodied in the tables accompanying the paper.

One of the principal deductions from these experiments was the "straight-line" law of steam-consumption; and it was shown by diagrams that the *total* water for the horse-power corresponding to any mean pressure P, was W + K P., where W was the water which would be used by the engine at zero mean pressure (through initial condensation, radiation and conduction), supposing it were frictionless, and K was the water per hour required to produce each pound of mean pressure. These factors were shown to vary with the conditions under which the engine was working.

Eighteen of the trials were planned to assist in determining the law connecting initial condensation with revolutions; and it was found that in the high-pressure cylinder at high mean pressures the total condensation per unit of time was directly proportional to the square root of the number of revolutions per unit of time. As the mean pressure was diminished, the condensation became more and more nearly constant at all speeds; and finally, at low mean pressures, the law appeared to be reversed. For the low-pressure cylinder, the law was modified.

The important question of the changing proportions of steam and water present during the expansive part of the stroke was investigated by the $\theta\ \phi$ diagram. The matter was first examined theoretically by considering the effect of a thin liner of infinitely conducting matter, and a curve was drawn on the $\theta\ \phi$ diagram showing the rate at which the steam initially condensed in warming up the liner from the exhaust to the initial temperature was re-evaporated as the expansion proceeded. The actual re-evaporation, as obtained by measurement of the indicator cards was compared with this theoretical re-evaporation, the difference measuring the delay in the return of the heat from the liner to the steam. The losses due to conduction and radiation, to passage through ports, and to incomplete expansion, could also be shown on the $\theta\ \phi$ diagram.

The question of the economical advantage of reducing the power by automatic cut-off *versus* throttling was discussed. Broadly, the result was that the gain by varying the expansion was large for a simple engine, moderate for a compound engine, and, for a triple engine, almost inappreciable. It further appeared that the gain at high speeds was greater than at low speeds.

A few trials made with the cylinders steam-jacketed showed a slight gain, but further experiments were required to show whether the gain was likely to be worth the extra trouble and expense involved.

The missing steam at cut-off varied in the trials to even a greater extent than it did in the non-condensing trials—the amount being much affected by the range of temperature, the density of the steam, and by other conditions.

It appeared that, under all circumstances, the triple-condensing engine showed an advantage over the compound in regard to steam-consumption; but that, except for very large engines, the compound-transfer engine was probably the best for pressures below 150 lbs. (absolute) pressure per square inch.

ETHNOLOGICAL OBSERVATIONS IN AUSTRALIA.

SOME time ago Mr. R. Etheridge, jun., carried on a series of geological and ethnological investigations in the valley of the Wollondilly River, at its junction with the Nattai River, New South Wales; and in the latest number of the "Records of the Australian Museum" (vol. ii. No. 4) he gives an interesting account of the various facts he had occasion to study. The following is the greater part of the passage in which he records his ethnological observations:—

The aborigines of the Wollondilly and Nattai Valleys, must, from local accounts, have existed in considerable numbers, and are now only represented by interments, carved trees, wizards' hands, and charcoal drawings in rock shelters along the precipitous escarpments.

The first objects investigated under this head were the "Hands-on-the-Rock." The "rock" consists of a huge mass of Hawkesbury Sandstone, about seventeen feet in breadth and length, hollowed out on the side overlooking the river to the extent of six feet. It is perched on the side of a gentle rise from the Wollondilly, having rolled from the higher ground above, and alongside the track from the Nattai Junction to Cox's River, in the immediate south-west corner of the Parish Werriberri. The cavernous front of the rock is fifteen feet

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[1] "On the Putrefactive Processes in the Large Intestine of Man and on the Microbes Causing Them," by M. Lumft. "On the Micro-organisms in the Organs of Choleraic Patients," by M. L. de Rekowski. "Contributions to the Study of Chemical Processes in the Intestines of Man," by M. Jakowski.

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